Argonne NATIONAL LABORATORY

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Electricity Market Complex Adaptive System (EMCAS)

Model Introduction

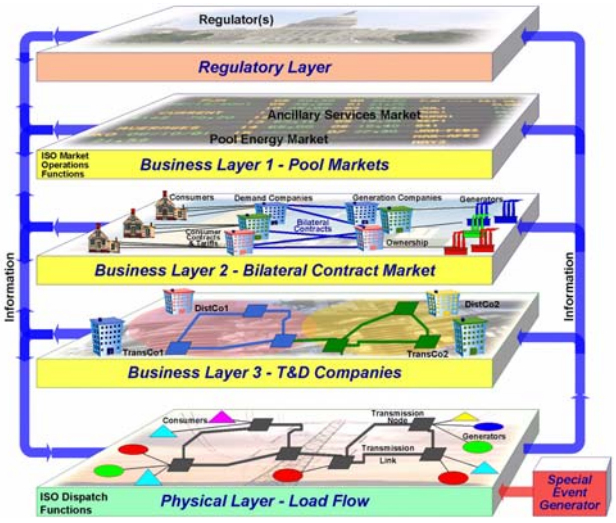
Decision and Information Sciences Division
Center for Energy, Environmental, and Economic Systems Analysis

Electricity Market Complex Adaptive System (EMCAS)

EMCAS is the latest and most advanced tool in Argonne's suite of power systems analysis software

Description

EMCAS uses a novel agent-based modeling approach to simulate the operation of today's complex power systems. EMCAS can be used as an "electronic-laboratory" to probe the possible operational and economic impacts on the power system of various external events. Market participants are represented as "agents" with their own set of objectives, decision-making rules, and behavioral patterns. Agents are modeled as independent entities that make decisions and take actions using limited and/or uncertain information available to them, similar to how organizations and individuals operate in the real world. EMCAS includes all the entities participating in power markets, including consumers, generation companies (GenCos), Transmission Companies (TransCos), Distribution Companies (DisCos), Demand Companies (DemCos), Independent System Operators (ISO) or Regional Transmission Organizations (RTO), and regulators.



All the entities, or agents, interact on several different layers. In the physical layer, the transmission grid is represented on a detailed bus and branch level to allow a full-scale load flow analysis. Here, the system operator dispatches the available generators to meet the load while maintaining the constraints and limitations of the transmission system. If needed, this representation can be simplified by developing a "reduced" transmission network. Several business layers are used to model the various forward markets (e.g., pool energy markets, bilateral contract market) where generation companies can buy and sell power. The operation of the transmission and distribution companies is included in a separate business layer. On the regulatory layer the user can set various operational and markets rules.

EMCAS simulates the operation of a power system and computes electricity prices for each hour and each location in the transmission network. Electricity prices are driven by demand for electricity, cost of electricity production, the extent of transmission congestion, external random or non-random events, such as unit outages or system disruptions, and company strategies. Model results include the economic impacts on individual companies and consumer groups under various scenarios.

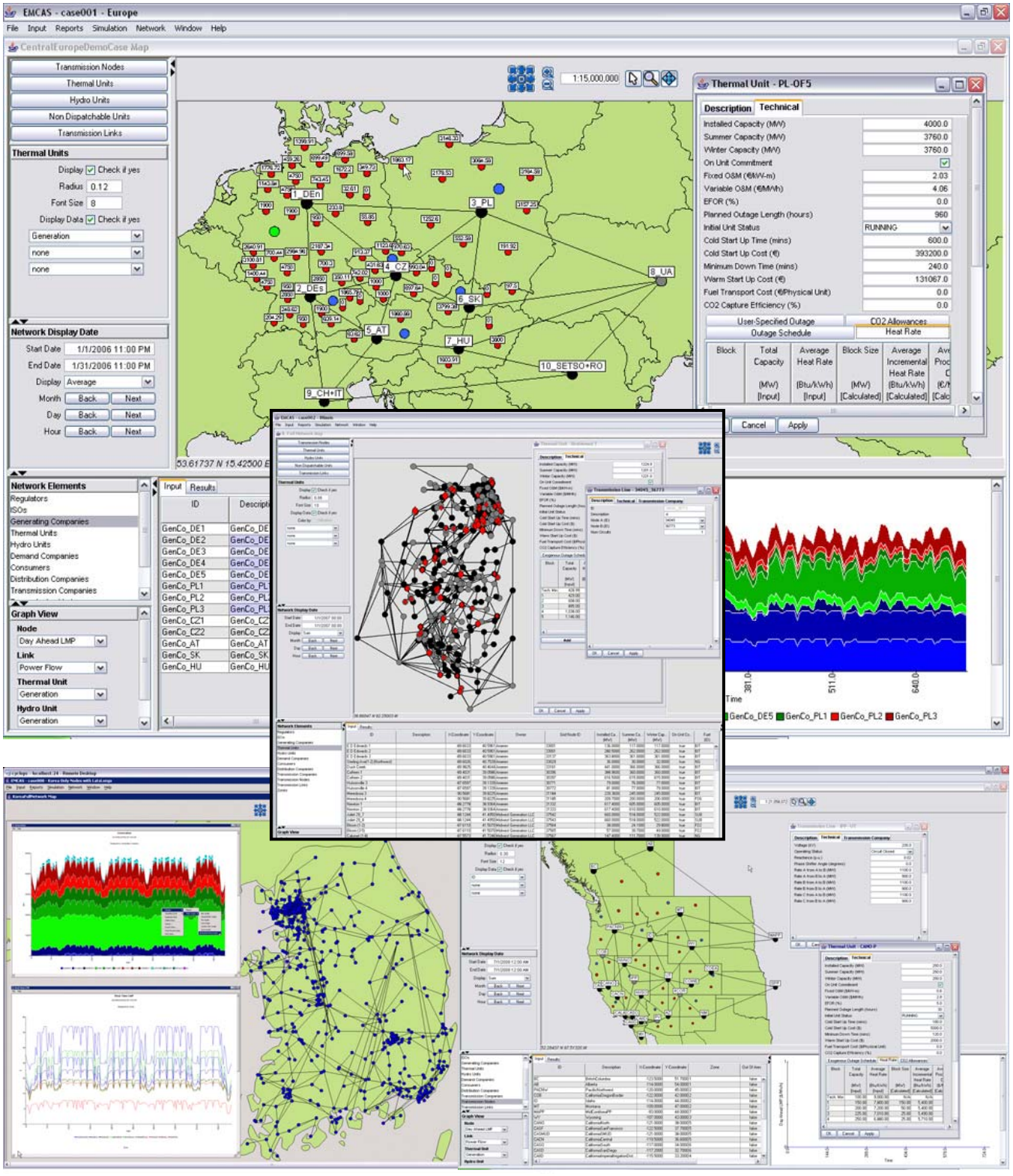
Model and Data Interfaces

EMCAS uses a graphical user interface to develop market configurations, display model inputs, and analyze simulation results (see screen captures on next page). Results are stored in HDF format and can be quickly retrieved or exported in text and spreadsheet formats.

Adaptability to Local Market and System Conditions

The EMCAS model is fully customizable and not hardwired to any particular system. The user builds the system configuration either within the EMCAS graphical user interface or by preparing and importing a set of well-defined input files. Network configurations can be simple and aggregate consisting of a few to several dozen

network nodes and links, or detailed bus-level representations with several thousand network elements. The level of detail largely depends on data availability and particular analysis objectives. The screen captures below show several power market representations.



Software Features

EMCAS has the capability to simulate markets using either a uniform or discriminatory auction format. The model also includes bilateral contracts. Real-time prices are calculated in a real-time dispatch using a DC optimal power flow model. In early 2006 we added the capability to analyze power system investment and expansion issues using a multi-agent-based profit maximization approach. The newest version includes an additional cost-minimization dynamic programming investment algorithm for regulated markets. EMCAS uses a simplified representation of ancillary services markets (no separate bidding). Some of the key strengths of the EMCAS agent-based modeling approach include:

- Represents multiple market participants (agents) with decentralized decision-making; each agent may have its own set of strategies, risk preferences, and objectives;
- Alternative company strategies can be simulated;
- Incorporates agent learning and adaptation based on performance and changing conditions;
- Market rules can be tested before they are implemented; and
- Two different investment modeling algorithms that use either dynamic programming cost minimization or company-level profit maximization.

Availability of Training

An introductory course/workshop can be three days to two weeks. In a 2-week course, the first week covers the theoretical background of agent-based modeling, complex adaptive systems, and detailed EMCAS agent implementation issues. The second week continues with the theoretical background on individual software components but also offers hands-on simulations of several test cases, including a simple 11-node network with 24 generators and 8 generation company agents, as well as a regional 10-node Central-European case with 68 aggregate thermal generators, 13 major generation companies, as well as hydro and wind power resources.

Several 2-week EMCAS courses have been conducted at Argonne in 2005, 2006, and 2007. The courses were attended by 68 participants from over 20 countries, including Argentina, Belarus, Brazil, Bulgaria, Chile, Colombia, Croatia, Egypt, Hungary, Indonesia, Lithuania, Morocco, Philippines, Poland, Romania, Russia, South Africa, South Korea, Turkey, and Vietnam. Participants came from generation companies, research institutions, ISOs/TSOs/PXs, and regulatory offices. Similar courses will be held in the future. Please contact us for more details.

Software Runtime and Hardware Requirements

A network with 10 nodes (buses or locations), 70 aggregated thermal generating units, 13 generation companies, one transmission company, one ISO, and one regulator takes approximately 60 minutes for a one-year simulation (8760 hours) on a desktop PC with a 2.0 GHz AMD Athlon2000+ processor and 1 GB of RAM. For multi-year simulations, it is recommended to use a brand-new, high-end PC, preferably with multiple-core processors and 2+ GB of RAM.

Product Support

Product support is provided by staff at Argonne National Laboratory's Center for Energy, Environmental, and Economic Systems Analysis. Product support is provided using on-line meeting software, email, telephone, or site

visits. Product support includes regular product maintenance as well as specific consultations or support for customization requirements.

Model Demo

Please contact us if you are interested in a model demonstration. We can conduct a hands-on model demonstration at your facility or web-based remote demonstrations. A limited software demo version is now available to our training course participants. Please contact us for further details.

Educational Version

We also offer an educational version of EMCAS. This version is limited in terms of number of agents and network structure but allows researchers and students to investigate a variety of market issues. This version comes with a number of standard IEEE cases. Please contact us if you are interested in our educational version.

References

EMCAS was first applied for a regulatory commission in the mid-western United States. At the beginning of 2005, the software became commercially available and current clients include consulting companies, research institutes, power companies, transmission companies, and regulatory offices in South Korea, Portugal, and Croatia. Argonne is currently applying the tool for the U.S. Department of Energy to study nuclear power prospects in various countries as well as energy-water related issues in the Western United States.

Contact Information

The software is available via perpetual and annual end-user licenses. Educational licenses are also available. For more information on licensing and different model implementation support options, please contact us at the following address:

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